# Kinetic Physics in ICF Workshop: Discussion session – Day 1 – Experimental evidence

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Tuesday, April 5, 3:35 pm
481 R2004/2005

LLNL-PRES-692828
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

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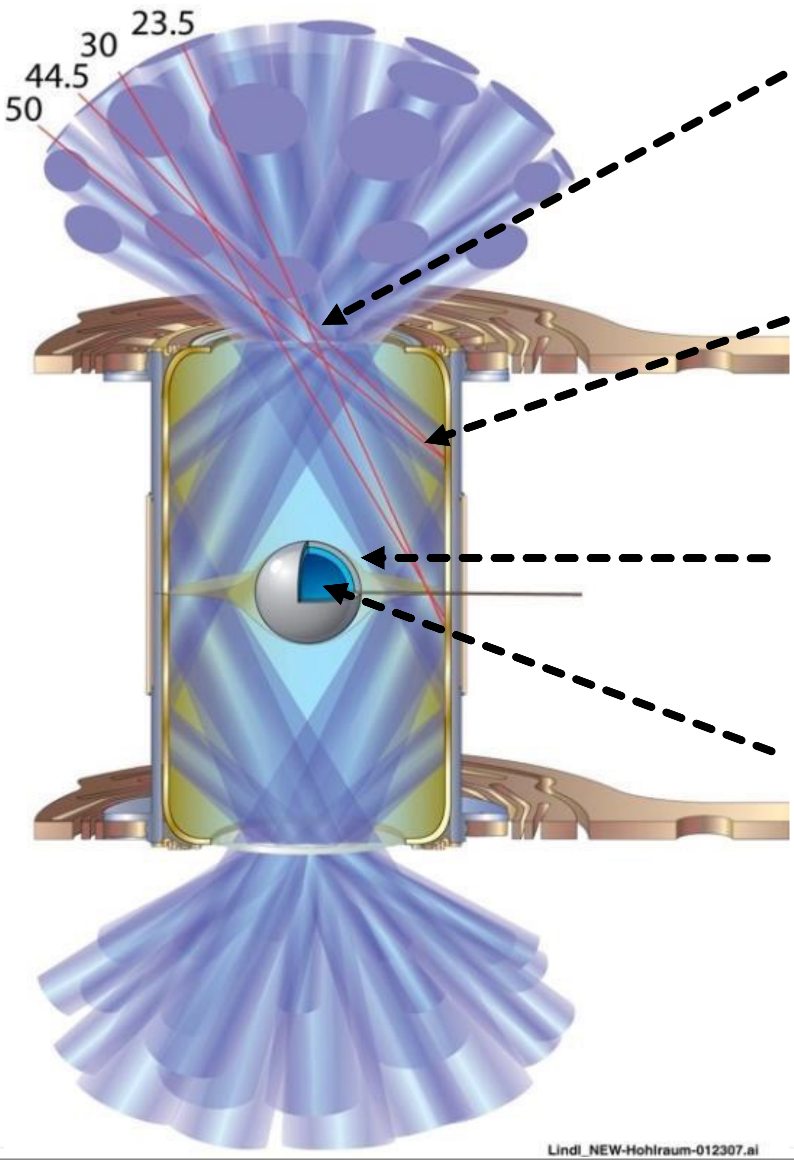
# Likely regions in ICF where kinetic physics may be important:




- **LEH and laser/gas interactions**
- **Hohlraum gas/wall interface**
  1. *S. LePape* — *C-C, C-Al, C-Au interpenetration*
  2. *A. Kemp* — *interpenetration PIC simulations*
  3. *C. K. Li* — *Radiography of field structures*
- **Ablator**
  1. *S. Ross* — *ion species separation in CH*
- **Shock dynamics, hot spot assembly, burn**
- **Other**
  1. *M. Rosenberg* — *Exploding pusher yield anomalies*
  2. *H. Herrmann* — *Direct-drive yield anomalies*
  3. *S. Hsu* — *D/Ar separation*
  4. *D. Casey* — *Yield ratios in DT expts*
  5. *M. Schmitt* — *Hydro/kinetic mix via gammas*
  6. *J. Fernandez* — *superdiffusive plasma mix*
  7. *H. Sio* — *x-ray vs nuclear emission history*
  8. *R. Hua* — *Shock front structure radiography*
  9. *H. Rinderknecht* — *Thermal decoupling in 2-species*

# Questions to guide discussion:

1. **Importance:** How would this phenomenon impact the performance of an ICF implosion?
   - How would it impact observables?
   - What back-of-the-envelope calculation or test simulation supports the proposed impact(s)?

2. **Next Steps:** What proposed experiment or test problem would clearly demonstrate or benchmark this effect?

# 1. Quick overview of today's presentations:

**Anomalies in NIF dataset**

- Yields from HF campaign seems to be (mostly) reasonably well understood by 2D-simulations
  - 3D simulations can actually underperform compared to experiments

LPI/hot electron sources

- Measured DSR (~ρR) is often lower than 2D-predictions

DT temperature hard to ex
DD can be explained

- Brysk ion temperatures (DD, DT) are higher than simulated
  - This seems to be too large to be explained by flow velocity in some cases
  - Temperature difference subsists relative to 3D simulations (more tomorrow)
- DT/DD yield ratio varies, but is often lower than expected (possibly due to fill)
- There may be some missing underlying physics in the simulations w.r.t. ablator: less compact in experiments than in simulations.

All shots peak at 10^16
Is the yield agreement in "hindsight"?

# 1. Quick overview of today's presentations:

**Kinetic physics in the fuel – species separation**

- Yield anomalies seem to occur at high- and middle- $N_K$ (Rosenberg, Herrmann, Casey) but maybe not at very low-$N_K$ (Casey)
  - Species separation supported by inverse Rygg effect (Herrmann)
  - Temperature anomalies still occur?
  - What effect does this have on entropy?

Joule heating from shock E-field

Au bubble diffusion:
Important physics to nail down

- Time-dependent fuel species separation observed using D + Ar dopant (Hsu)
  - Why is Ar depleted ahead of shock?
  - [also significant species separation (~20%) @ $N_K$ ~ 0.3 (Rinderknecht, not shown)]

**Kinetic physics in fuel/ablator interface – diffusion mix**

Magnetic fields in hotspot
Inhibit thermal conductivity

- Kinetic Mix was observed in gas-filled implosions (Schmitt):
- "Superdiffusive" mix seen in PIC simulations, experiments being performed (Fernandez)
  - This could follow from 2nd, 3rd order corrections to diffusion approx?
  - Is low-level tail correction to diffusive ablator mix relevant in layered implosions?

# 1. Quick overview of today's presentations:

**Kinetic physics in the ablator**

- Ablating CH shows species separation (Ross)
  - Does this persist? Energy loss / entropy gain from separation, resistive heating?
  - Ablator physics doesn't seem to be dominant in NIF implosions

Adds to the "zoo"
In the hohlraum

- Radiographs show filamentary B-field structure around ablator in direct-drive (Li)

**Kinetic physics in the hohlraum**

LPI -> electron preheat

- Self-emission & TS platform demonstrated for Au/C interpenetration (LePape)
  - Au-C forms a 'ridge'; Al-C penetrates further.
  - Interpenetration of Au-C, Al-C, C-C measured with Thomson scattering
- Fully-kinetic PIC simulations of interpenetration: hydro answer looks similar to PIC answer except for ~ single cell spikes in density (Kemp)
  - Can we compare PIC and other simulation techniques to address NVH hohlraum?
- Radiography shows strong field structures in the hohlraum and near LEH (Li)
  - Expect more instability growth NIF-duration experiments

*How do E,B fields and interpenetration change hohlraum performance?*

- *Electron transport properties?*
- *Diagnosis for other effects?*

Modeling B fields -> simulat
What is B-field impact on ca

# 1. Quick overview of today's presentations:

**Kinetic physics in shock fronts/shocked plasmas**

- Time-dependent capabilities exist for nuclear & x-ray emission history at ~10ps resolution (Sio)
- Shock front E-fields measured ($\Phi$=8 kV) with proton radiography (Hua)
  — 2-field structure suggests interface + shock front
- Unequilibrated ion species observed in low-$N_K$ (Rinderknecht)

*How do details of vapor state (E-fields, equilibration, shock structure, …) affect equilibration, initial conditions for deceleration phase?*

# 2. Experiments seem to have a tradeoff between *clarity* and *relevance.*

<u>Type of experiment</u>

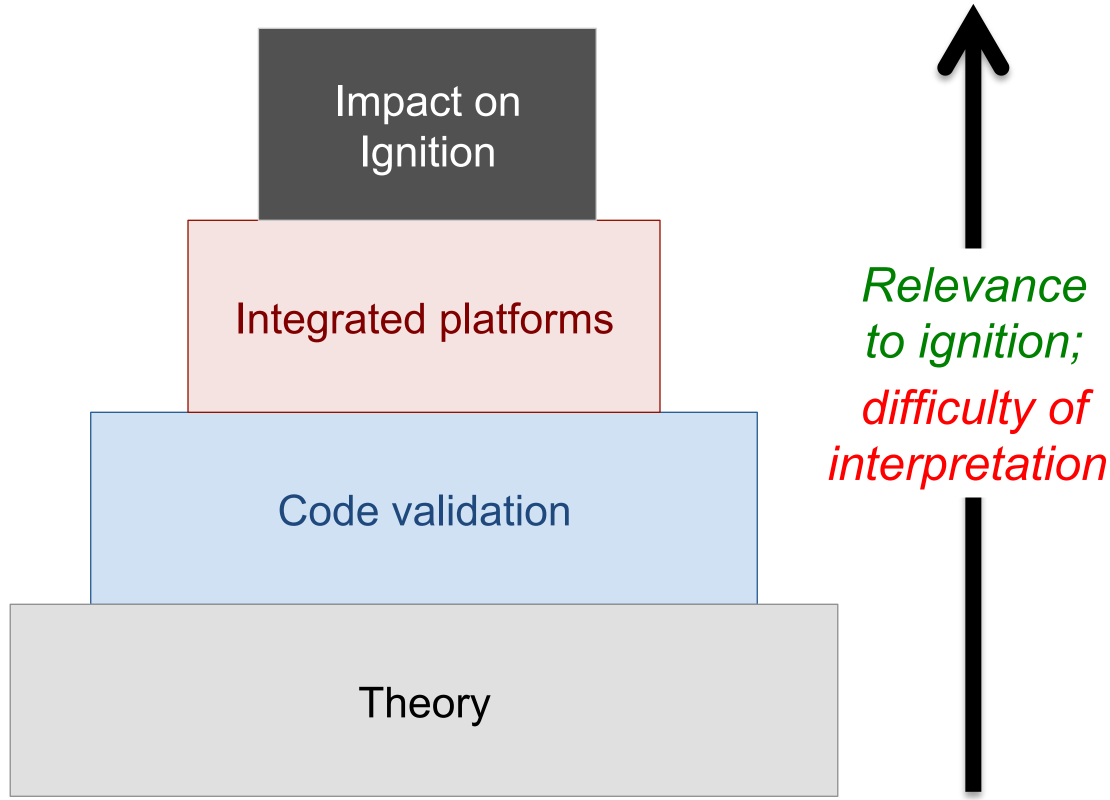
Ignition designs:
- *Designed around performance*

Surrogate implosions

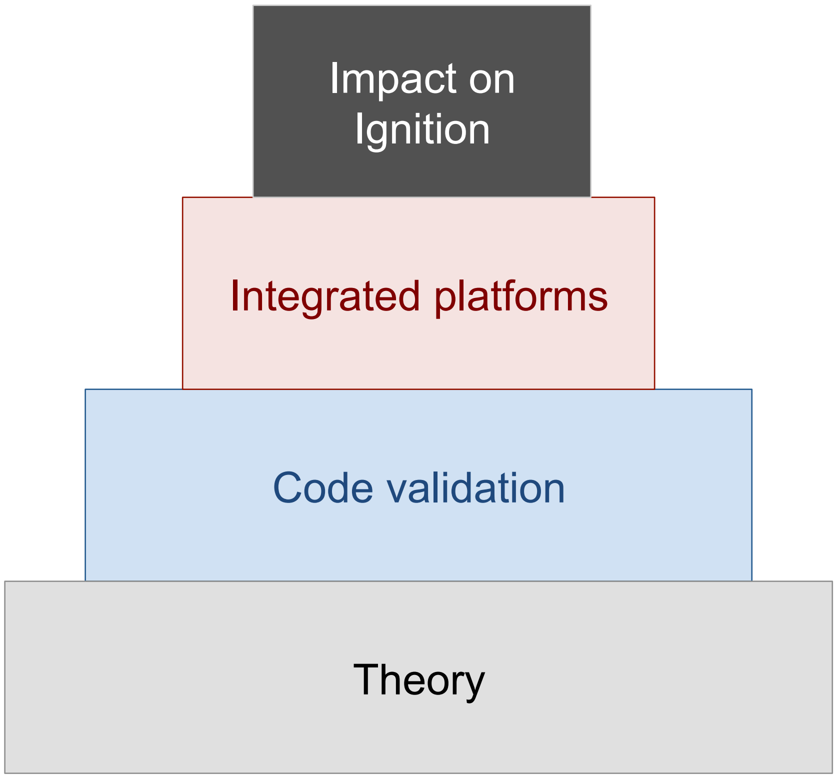
Component tests

Fundamental physics:
- *Designed around diagnosis*
- *as simple as possible*

<u>How data is used</u>



# 2. Two complementary approaches to experiments will help make the case for kinetic physics in ICF




**Approach A**

*Incorporate results into simulations*

*Study fundamental physics*

**Approach B**

*Robust scaling study near the regime of interest*

# Approach A:
# What are the best fundamental physics experiments we can do?

What parts require expanation?
Low mode drive asymmetry
Oggie multipliers
Ablator under long coast conditions
– rhoR

Incorporate results into simulations

Study fundamental physics

- **LEH and laser/gas interactions**
- **Hohlraum gas/wall interface**
  - *1D interpenetration experiments (LePape)*
- **Ablator**
- **Shock dynamics, hot spot assembly, burn**
  - *Thomson scattering of shock front structure (Rinderknecht)*
  - *Multispecies fuel effects in DT exploding pushers (Petrasso)*

  PSTD – time resolved burn info
- **Other**

# Approach B:
# What scaling experiments can be done near ignition conditions?

*Robust scaling study near the regime of interest*

- **LEH and laser/gas interactions**

  Hot electrons / backscatter consistency?

- **Hohlraum gas/wall interface**
  - *Changing hohlraum and/or gas material → gradient in Z? (Amendt)*
  - *Proton radiography of hohlraums (Li)*

  NVH gas density scaling

  Temperature, heat capacity of central gas (dot spectroscopy)

- **Ablator**

- **Shock dynamics, hot spot assembly, burn**
  - *Wetted foam – vary initial gas density from 0.3 – 10 mg/cc (Zylstra, LANL)*
  - *"DT Gigabar" – vary initial vapor radius from 0 – 95% of shell radius (Rygg, Ping)*

- **Other**

## On Thursday we will come back to this discussion with proposed experiments to examine each effect.

Please continue thinking and talking about these ideas, and send a brief description (1 slide) of your proposed experimental campaigns to rinderknecht1@llnl.gov.

Thank you!